Weed Science 2013 61:543–548

Giant Ragweed (*Ambrosia trifida*) Competition in Cotton

Kelly A. Barnett and Lawrence E. Steckel*

Glyphosate-resistant (GR) weeds, including giant ragweed, are among the most challenging weeds for growers to control in cotton. A field study was conducted in 2011 and 2012 to determine the competitiveness of giant ragweed with densities of 0, 0.1, 0.2, 0.4, 0.8, or 1.6 plants m^{-1} of row. Early in the growing season, giant ragweed competition with densities of at least 0.8 plants m^{-1} row reduced cotton height compared with the weed-free control. Based on node above white flower (NAWF) and node above cracked boll (NACB) data, a delay in cotton maturity was observed for treatments with giant ragweed present at a density of 1.6 m^{-1} of cotton row for NAWF and 0.8 m^{-1} or 1.6 m^{-1} of row for NACB. Lint yield losses of 50% were estimated for cotton with rows growing along side of giant ragweed at a density of 0.26 plants m^{-1} row. Cotton in rows located 140 cm away from giant ragweed required an estimated 1.85 plants m^{-1} row to reduce yield by 50%. These data suggest that giant ragweed sphere of influence was at least 1 m wide. Cotton fiber quality was not affected by giant ragweed at any density. Giant ragweed is a highly competitive weed in cotton, even at low densities, and efforts should be implemented to control giant ragweed early in the season to prevent cotton yield loss.

Nomenclature: Cotton, *Gossypium hirsutum* L.; giant ragweed, *Ambrosia trifida* L.; glyphosate resistant, GR.
Key words: Giant ragweed, glyphosate resistance, herbicide resistance.

Giant ragweed is a problematic summer annual weed in agronomic crops throughout the United States (Baysinger and Sims 1991; Harrison et al. 2001; Johnson et al. 2006; Webster et al. 1994). Giant ragweed is primarily known for being a weed in floodplains, fence rows, and ditch banks but has adapted to become competitive in agronomic crops more recently (Bassett and Crompton 1982; Bryson and DeFelice 2009; Hartnett et al. 1987; Johnson et al. 2006; Steckel 2007). Although giant ragweed is highly competitive in agronomic crops, it is interesting to note that it has a fairly low fecundity and seed survival rate when compared with other weed species (Harrison et al. 2001). However, giant ragweed's rapid growth, wide emergence window, and ability to grow in diverse environments contribute to its success as a major weed in corn, soybean, and cotton (Abul-Fatih and Bazzaz 1979b; Harrison et al. 2001).

Once established, giant ragweed continues to thrive in its environment through rapid biomass accumulation and eventually suppresses other plant species (Abul-Fatih and Bazzaz 1979a; Jurik 1991). Giant ragweed's growth in height varies based on crop and environment, but it typically grows 0.3 to 1.5 m taller than the crop with which it is competing (Johnson et al. 2006). Bazzaz and Carlson (1979) reported that giant ragweed has a high photosynthetic rate compared to most other annual species, which contributes to its ability to grow rapidly. In addition, giant ragweed's emergence window has evolved over the years, making it more challenging for growers to control. In the 1960s and 1970s, studies in Illinois indicated that giant ragweed seedlings started emerging in the beginning of March and continued through the first part of May (Abul-Fatih and Bazzaz 1979a; Stoller and Wax 1973). Presently, giant ragweed in agronomic fields may start to emerge in mid-March and continue through mid-July (Harrison et al. 2001; Schutte et al. 2012; Steckel 2007). This wide emergence window makes it difficult to control because early germinating plants may become established before effective weed control measures can be taken, and plants that germinate in late June through July may escape postemergence weed control measures (Harrison et al. 2001; Schutte et al. 2008).

Giant ragweed is a common issue for growers in Midwestern corn and soybean fields. In the early 1990s, Ohio growers indicated that giant ragweed was one of the most severe weed problems (Loux and Berry 1991). In Indiana, 30% of growers indicated giant ragweed was an issue on their farm, making giant ragweed the most problematic weed for growers (Gibson et al. 2005). The introduction of GR crops including corn, cotton, and soybean, has provided POST options for difficult-to-control weeds such as giant ragweed. Glyphosate has been used heavily in cotton production since the introduction of GR cotton in 1997 because of its broad-spectrum control of most grass and broadleaf species (Askew et al. 2002; Baylis 2000; Duke and Powles 2009; Gianessi 2005; Owen and Zelaya 2005). However, GR giant ragweed biotypes have evolved in several states throughout the United States. Although GR giant ragweed is found primarily in Midwest corn and soybean states such as Indiana, Iowa, Kansas, Minnesota, Missouri, and Ohio, it is also prevalent in cotton growing states throughout the south including Arkansas, Mississippi, and Tennessee (Heap 2012; Norsworthy et al. 2010, 2011). GR giant ragweed was first confirmed in Tennessee in 2007 and has continued to become problematic throughout the state (Norsworthy et al. 2010). Herbicide resistance and the wider emergence window of giant ragweed present new challenges for cotton growers. Giant ragweed emerges early, and burndown applications made prior to planting are often not as effective due to the size of giant ragweed and herbicide resistance.

Previous studies have evaluated the impact of giant ragweed in corn and soybean. In corn, one giant ragweed plant per 10 m^2 reduced yields by 13.6%, making it one of the most competitive annual weeds in corn (Harrison et al. 2001). Giant ragweed is also one of the most competitive weeds in soybean where less than two giant ragweed plants per 9 m^{-1} of row reduced yields by as much as 50% (Baysinger and Sims 1991). Another study in Ohio indicated that one giant ragweed plant per m^2 reduced soybean yields between 45 and 77% (Webster et al. 1994). Webster et al. (1994) also determined that giant ragweed utilizes two different growth habits that allow it to compete effectively with soybean. It

DOI: 10.1614/WS-D-12-00169.1
* First and second authors: Graduate Research Assistant and Associate Professor, University of Tennessee, Department of Plant Sciences, 605 Airways Blvd., Jackson, TN 38301. Corresponding author's E-mail: lsteckel@utk.edu

emerges early and outgrows the crop early in the season with little growth within the canopy, but also grows competitively with little sunlight under the soybean canopy later in the season. This allows giant ragweed to compete at very low densities in soybean.

The effects of giant ragweed competition in cotton production are not known. However, other weeds have been reported to substantially reduce cotton lint yield. Tumble pigweed (*Amaranthus albus* L.) and silverleaf nightshade (*Solanum elaeagnifolium* Cav.) had a lint yield loss threshold of 0.4 to 1.6 plants m^{-1} row. Ivyleaf morningglory [*Ipomoea hederacea* Jacq.] reduced lint yield almost 6% for each additional weed per 10-m row for up to 8.7 plants per 10-m row, where after reduction was only 0.5% with each additional weed (Green et al. 1987; Rogers et al. 1996; Rushing et al. 1985b). Other weed species such as buffalobur (*Solanum rostratum* Dunal) reduced lint yield 22 to 32% at a density of 0.8 plants m^{-1} row at one location and 3.2 plants m^{-1} row at another location. Sicklepod [*Senna obtusifolia* (L.) H.S. Irwin & Barneby] and tall morningglory [*Ipomoea purpurea* (L.) Roth] reduced lint yields by 10 to 40% at a density of 8 plants per 7.3-m row (Buchanan and Burns 1971; Rushing et al. 1985a).

We suspect that since similar low densities of Palmer amaranth (*Amaranthus palmeri* (S.) Wats.] and giant ragweed have very high yield reductions in corn and soybean, cotton yield loss at low densities of giant ragweed may be very high. Giant ragweed is one of the most competitive weeds in corn and soybean, reducing yields at densities of 1 to 2 plants m^{-1} of row. The competitiveness of giant ragweed in other crops is similar to Palmer amaranth, which reduced corn yields by 11% at densities of 0.5 plants m^{-1} row (Massinga et al. 2001) and reduced soybean yields by 17% at densities of 0.33 plants m^{-1} row (Klingaman and Oliver 1994). In cotton, Palmer amaranth is one of the most competitive weeds with previous work demonstrating that 0.1 plants m^{-1} row reduced lint yields by 11 to 13% (Morgan et al. 2001; Rowland et al. 1999).

The evidence for lint yield reductions due to competition with other weed species is clear, but fiber quality is another important aspect of cotton production. Weed interference may reduce fiber quality by affecting fiber length, uniformity, strength, or micronaire, which is a measure of cotton fiber diameter. Previous weed interference studies have indicated that certain weed species including hogpotato [*Hoffmanseggia glauca* (Ortega) Eifert], unicorn-plant [*Proboscidea louisianica* (Mill) Thell.], ivyleaf morningglory, and buffalobur can reduce fiber quality at high densities (Castner et al. 1989; Mercer et al. 1987; Rogers et al. 1996; Rushing et al. 1985a). However, other weeds such as sicklepod, tall morningglory, silverleaf nightshade, and tumble pigweed had no effect on any aspect of fiber quality (Buchanan and Burns 1971; Green et al. 1987; Rushing et al. 1985b). Growers with giant ragweed infestations in their fields often ask how much yield loss can be expected with minor infestations (Authors' personal experiences). The objectives of this study were to determine the effect of varying giant ragweed densities on cotton growth, development, lint yield, and fiber quality.

Materials and Methods

An experiment to determine the competitiveness of giant ragweed in cotton at various densities was conducted at the West Tennessee Research and Experiment Center (WTREC) in Jackson, TN, in 2011 and 2012. Soil type was a Lexington silt loam (Fine-silty, mixed, active, thermic Ultic Hapludalfs) with an organic matter of 1.5% and a pH of 6.0.

Prior to planting and using the previous year's cotton stubble as row markers, different densities of giant ragweed were established between the center two rows of four-row main plots. Plots were 9 m in length, and row spacing was 96 cm. In March of 2011, giant ragweed seedlings were collected from fields at the WTREC and transplanted at a density of 0, 1, 2, 4, 8, or 16 plants per plot, or to 0, 0.1, 0.2, 0.4, 0.8, or 1.6 plants m^{-1} of cotton row, respectively. In 2012, the same densities of giant ragweed were established from seedlings that emerged within the plots or were transplanted as needed during March. Giant ragweed height at planting averaged 15 cm in height but ranged from 10 to 25 cm in height. A randomized complete block design with four replications was utilized for this field experiment.

A Phytogen 375 WRF (Dow AgroSciences, Indianapolis, IN) cotton variety was planted on May 9, 2011, and on April 24, 2012. A no-tillage system was utilized, and all other production practices followed University recommendations. Each year, an early burndown application of glyphosate (Roundup WeatherMax, Monsanto Co., St. Louis, MO) at a rate of 876 g ae ha^{-1} plus 280 g ae ha^{-1} dicamba (Clarity, BASF Ag Products, Research Triangle Park, NC) was followed with an application of paraquat (Gramoxone Inteon, Syngenta Crop Protection Inc., Greensboro, NC) at 840 g ai ha^{-1} plus NIS at 0.25% v/v prior to giant ragweed transplanting. At planting, weed control was maintained with an application of paraquat at 840 g ai ha^{-1} plus NIS at 0.25% v/v plus pendimethalin (Prowl H_20, BASF Ag Products, Research Triangle Park, NC) at 1,065 g ai ha^{-1} and fluometuron (Cotoran, Makhteshim Agan of North America Inc., Raleigh, NC) at 1,120 g ai ha^{-1}. After cotton emergence, plots were maintained with an application of glyphosate at 840 g ae ha^{-1} plus s-metolachlor (Dual Magnum, Syngenta Crop Protection Inc., Greensboro, NC) at 1,068 g ai ha^{-1}. Plots were maintained as weed free throughout the growing season with the exception of the specific giant ragweed densities. Giant ragweed plants were covered with pots to prevent injury from herbicide applications, and weed control was maintained through the rest of the growing season with hand weeding.

Cotton heights were recorded at the four-, eight-, and twelve-leaf stages for five plants from the two center rows and then averaged for each plot. Plants were randomly selected and measured from the soil level to the top of the plant. NAWF and NACB ratings were also taken from five randomly selected cotton plants in each plot and then averaged for each plot. NAWF was determined by counting the number of nodes from the highest first position white flower to the node of the upper most fully expanded leaf. NACB was determined by counting the number of nodes above the highest node of a first position cracked boll to the highest node with a harvestable boll. Prior to harvest, all giant ragweed plants were removed from plots, and two randomly selected giant ragweed plants from each plot were weighed. Yield data were collected from the two center rows of each plot as well as the two outside rows. Plots were harvested with a spindle picker modified for small-plot research. Seed cotton samples were collected to determine lint cotton yield and fiber quality. Samples were ginned using a laboratory gin without

Table 1. Effect of giant ragweed density on cotton height, node above white flower (NAWF), and node above cracked boll (NACB) and on giant ragweed biomass.

Giant ragweed density	Cotton height[a]			NAWF[b]	NACB[c]	Giant ragweed biomass[d]
	4-leaf	8-leaf	12-leaf			
# ha^{-1} (# m^{-1})		cm		#	#	kg
0	15 a[e]	28 a	50 a	4.1 a	7.4 a	.[f] a
600 (0.1)	14 a	25 ab	46 a	3.8 a	7.4 a	4.9 a
1,200 (0.2)	13 b	25 ab	43 ab	4.0 a	7.1 a	6.0 a
2,400 (0.4)	12 b	22 b	37 bc	4.3 a	8.7 ab	5.4 a
4,800 (0.8)	10 c	18 c	33 cd	4.1 a	9.5 b	4.4 a
9,600 (1.6)	9 d	14 d	25 d	6.2 b	9.6 b	3.7 a

[a] Cotton height recorded for five plants per plot and then averaged.
[b] NAWF recorded for five plants per plot and then averaged.
[c] NACB recorded for five plants per plot and then averaged.
[d] Giant ragweed biomass collected at harvest for two plants per plot and then averaged.
[e] Means followed by the same letter are not different according to Fisher's Protected LSD at $P \leq 0.05$.
[f] Means are not statistically different according to Fisher's Protected LSD at $P \leq 0.05$.

lint cleaning. Lint samples were then sent to Texas Tech University in 2011 and Cotton Incorporated in 2012 to determine fiber length, length uniformity, strength, micronaire, and color on samples collected from the center two rows and the outside rows of each plot.

Data were analyzed using a two-parameter hyperbolic decay regression model in Sigma Plot (version 12.0; Systat Software, Inc.; Point Richmond, CA). This model fit the data well and is similar to the Cousens (1985) model except this model fits data with a negative slope, as observed in this study with decreasing lint yields at higher densities. In this model, lint yield of the center rows or lint yield of the border rows was regressed against the number of giant ragweed plants using a hyperbolic decay regression model (Equation 1) as described by SPSS (2002).

$$y = ab/(b + x) \qquad [1]$$

In this model, a is the asymptote or estimate of maximum lint yield of the center rows (or estimate of maximum lint yield of the border rows) and b is the estimate of the giant ragweed density at which 50% lint yield loss occurs.

Cotton height, NAWF, NACB, and giant ragweed biomass were analyzed using the PROC MIXED procedure in SAS (version 9.2; SAS Institute, Inc., Cary, NC), and an analysis of variance was used to test for significant main effects and interactions. Giant ragweed density was considered to be a fixed effect in the model, while year, replication (nested within years), and all interactions that included these factors were considered random effects. Means were separated using Fisher's Protected LSD test at the 0.05 significance level. Nontransformed means were utilized for cotton height, NAWF, NACB, and giant ragweed biomass because square root transformations did not improve the normality of the data.

Results and Discussion

Cotton Height. Cotton height was assessed at the four-leaf, eight-leaf, and twelve-leaf cotton stages (Table 1). Giant ragweed began to have an effect on cotton height as early as the four-leaf stage. Cotton height in the weed-free control was 15 cm and similar to cotton height for the density with 0.1 m^{-1} of row giant ragweed plants. Giant ragweed densities of 0.2 m^{-1} of row and 0.4 m^{-1} of row reduced heights similarly. Cotton height was further reduced in the densities with 0.8 m^{-1} of row and 1.6 m^{-1}. Due to early germination of giant ragweed, plants were already established and reduced cotton height early in the growing season.

At the eight-leaf stage, cotton height was further reduced due to giant ragweed competition. Cotton height was tallest for the weed-free control (Table 1). Cotton heights for the giant ragweed densities with 0.1 m^{-1} or 0.2 m^{-1} of row were not different from the weed-free control. Cotton height for the 0.4 m^{-1} of row giant ragweed density was shorter than the weed-free control. Densities with 0.8 m^{-1} or 1.6 m^{-1} of row giant ragweed plants had cotton plants that were considerably shorter than plants from all other densities. At the eight-leaf stage, cotton height had already been reduced by half for the density with 1.6 m^{-1} of row giant ragweed plants when compared with the weed-free control.

A similar trend followed for cotton heights measured at the twelve-leaf cotton stage. Cotton height was tallest for the weed-free control and did not differ from the 0.1 m^{-1} or 0.2 m^{-1} of row giant ragweed densities (Table 1). Cotton height for the 0.4 m^{-1} of row giant ragweed density was reduced from the weed-free control and the 0.1 m^{-1} of row giant ragweed density. As observed at the eight-leaf stage, cotton height at the twelve-leaf stage was reduced by half at the highest density when compared with the weed-free control. Similar competition studies with horseweed in cotton observed a reduction in cotton height at NAWF 5 (cotton cutout) due to weed competition (Steckel and Gwathmey 2009). Steckel and Gwathmey (2009) determined that horseweed could reduce cotton height at 0.7 or more plants m^{-1} when compared with a weed-free control. Compared to previous research, cotton height in the present study was measured earlier in the growing season, but we observed a similar reduction in cotton height at low densities of giant ragweed.

Node Above White Flower. NAWF is an important indicator of plant maturity and the number of bolls that a plant will produce during the growing season (Bourland et al. 2001). The effect of giant ragweed densities on NAWF was significant ($P = 0.0500$). All giant ragweed treatments from 0.1 m^{-1} to 0.8 m^{-1} of row plants had similar maturity ratings to the weed-free control, with a NAWF value of 4 (Table 1). The 1.6 m^{-1} of row giant ragweed density, however, had a NAWF rating of 6.2, indicating that high densities of giant ragweed delayed maturity.

Node Above Cracked Boll. NACB is an additional indicator of plant maturity and a decision making tool for timing the

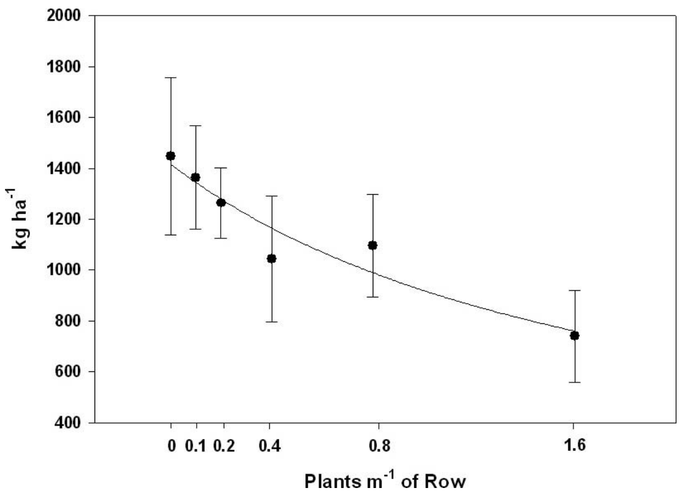

Figure 1. Cotton lint yield loss relative to increasing giant ragweed density between the rows (located 16 cm from giant ragweed) of cotton. Fitted line is calculated from the hyperbolic decay model (r^2 = 0.74). Estimated parameters are y = 1497*0.26/(0.26 + x).

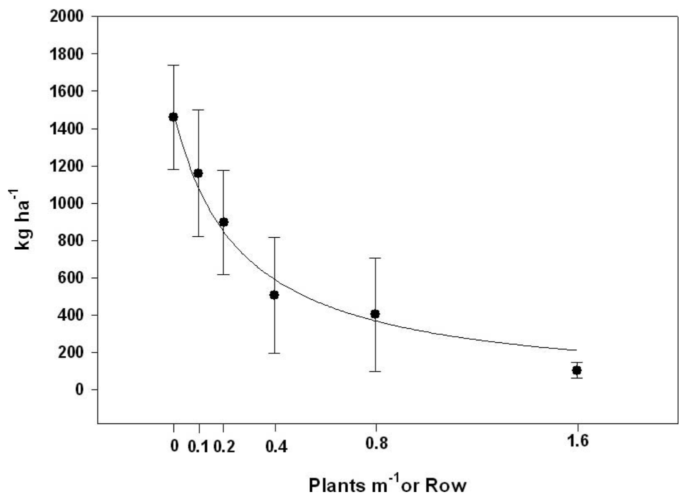

Figure 2. Cotton lint yield loss relative to increasing giant ragweed density on outside rows (located 96 to 140 cm from giant ragweed) of cotton. Fitted line is calculated from the hyperbolic decay model (r^2 = 0.51). Estimated parameters are y = y=1417*1.85/(1.85 + x).

application of boll openers and defoliants (Hake et al. 1996). A delay in NACB suggests potential harvest delays that may impact final lint yield. NACB evaluations for this study indicated that higher giant ragweed densities impacted NACB (P = 0.039). Giant ragweed densities that included 0.1 m^{-1}, 0.2 m^{-1}, and 0.4 m^{-1} of row plants were similar to the weed-free control (NACB = 7.4) and had NACB values of 7.4, 7.1, and 8.7, respectively (Table 1). However, giant ragweed densities of 0.8 m^{-1} or 1.6 m^{-1} of row had higher NACB values of 9.5 and 9.6, indicating a delay in maturity when compared with the giant ragweed free control.

Giant Ragweed Biomass. Giant ragweed biomass (Table 1) at the end of the growing season was also evaluated (P = 0.220). Other studies reported an effect of weed density for weeds growing in competition with cotton such as buffalobur, hogpotato, silverleaf nightshade, and unicorn-plant (Castner et al. 1989; Green et al. 1987; Mercer et al. 1987; Rushing et al. 1985a). In contrast to our study, there were no differences between the biomass of giant ragweed plants in treatments with 0.1 m^{-1} of row giant ragweed (4.9 kg per plant) and those with 1.6 m^{-1} of row (3.7 kg per plant).

Effect of Giant Ragweed Competition on Cotton Lint Yield. Cotton lint yield was closely associated to the density of giant ragweed plants. The model chosen $y = ab/(b + x)$ compared the independent variable of giant ragweed density on the *x* axis with the dependent variable of lint yield on the *y* axis for the lint yield of the center two rows. The hyperbolic decay model estimated the parameters to be y = 1,497*0.26/(0.26 + x) and explained the relationship well (r^2 = 0.74) (Figure 1). Lint yield in the center two rows of plots with the highest density of 1.6 giant ragweed plants m^{-1} of row reduced yield by about 94%. The regression model estimated that a density of 0.26 giant ragweed m^{-1} of row would result in a 50% lint yield loss (P > 0.0001) from the maximum yield in this study. This result would indicate that giant ragweed is one of the most competitive weeds in the world to cotton production and even rivals the competitive ability of common cocklebur and Palmer amaranth. Rowland et al. (1999) reported that Palmer amaranth needed 0.38 plants m^{-1} of cotton row to reduce lint yield by 50%. Morgan et al. (2001) reported that 0.87 Palmer amaranth m^{-1} was needed to reduce cotton yield by 50%. Palmer amaranth is considered one of the most competitive weeds in the southern United States (Webster 2005). These data would suggest that giant ragweed is also more competitive than cocklebur where 0.53 to 0.37 plants m^{-1} of row were needed to reduce cotton yield by 50% (Snipes et al. 1982).

The same hyperbolic decay model was used to evaluate treatment effects on lint yield in the outside rows of the plots, which were planted 96 to 140 cm away from the giant ragweed. Cotton lint yield for the outside rows was also related to the density of giant ragweed plants in the center of the plot. Lint yields from outside rows were reduced if more ragweed plants were present in the center of the plots (Figure 2). The model estimated the parameters of the equation to be y = 1,417*1.85/(1.85 + x) with a fit of r^2 = 0.51. This would suggest that the sphere of influence of giant ragweed can extend to at least 96 cm. At a giant ragweed density of 1.6 m^{-1} of row reduced lint yield from 1,147 kg ha^{-1} (weed-free control) to 739 kg ha^{-1}. The regression model estimated a 50% lint yield loss in the outside rows of the plot when giant ragweed densities of 1.85 m^{-1} of row (P > 0.0001) were present in the center of the plot. These results are similar to the 49% lint yield loss we observed from giant ragweed present between the rows where densities of giant ragweed at 1.6 m^{-1} of row were present.

Effect of Giant Ragweed Competition on Cotton Fiber Quality. Cotton fiber quality was evaluated to determine if giant ragweed densities affected micronaire, strength, uniformity, or length for the center rows or outside rows. Previous research had indicated that some weed species including hogpotato, unicorn-plant, ivyleaf morningglory, and buffalobur reduced fiber quality at high densities (Castner et al. 1989; Mercer et al. 1987; Rogers et al. 1996; Rushing et al. 1985a). However, results from our studies indicated that giant ragweed did not affect any evaluated fiber quality characteristic for either the center two rows or outside rows (data not shown). This result was similar to previous work

https://doi.org/10.1614/WS-D-12-00169.1 Published online by Cambridge University Press

that showed that several weed species, including sicklepod, tall morningglory, silverleaf nightshade, Palmer amaranth, and tumble pigweed, reduced lint yield without affecting fiber quality (Buchanan and Burns 1971; Green et al. 1987; Rowland et al. 1999; Rushing et al. 1985b).

Cotton height, NAWF, NACB, and lint yield all were influenced by giant ragweed density. Our results were similar to previous studies that demonstrated that some weed species can reduce cotton height. Silverleaf nightshade reduced cotton height at densities of 0.4 or more plants m^{-1} of row (Green et al. 1987), while buffalobur reduced cotton height at densities of 1.6 or more plants m^{-1} of row (Rushing et al. 1985a) and unicorn-plant reduced cotton height at densities of 0.8 or more plants m^{-1} of row (Mercer et al. 1987). In addition, hogpotato reduced cotton height at several different cotton growth intervals after cotton emergence (Castner et al. 1989). In our studies, cotton height was reduced by as few as 0.2 to 0.4 giant ragweed m^{-1} of row indicating that giant ragweed had far more of an impact on cotton height than other weed species.

Previous research did not evaluate the effect of weed species on cotton maturity (NAWF and NACB). Our results indicated that some lint yield loss caused by giant ragweed may have resulted from a delay in cotton maturity. This study showed that 0.1 giant ragweed m^{-1} reduced lint yields by approximately 300 kg ha^{-1} or 20% (Figure 1). Results from this research were similar to previous studies. Rushing et al. (1985) found that buffalobur reduced lint yield (22%) at densities of 0.2 plants m^{-1} of row. Mercer et al. 1985 reported that unicorn-plant reduced cotton lint yield (20%) at densities of 0.1 plant m^{-1} row at one location. However, at two other locations, the density of 0.1 plants m^{-1} reduced yield only 11 and 13%. Results from this study indicated that giant ragweed is more competitive than many previously studied weed species and is even more competitive than Palmer amaranth (Morgan et al. 2001; Rowland et al. 1999). Our results agree with previous work evaluating the competitiveness of giant ragweed in corn and soybean, which showed that giant ragweed is indeed one of the most competitive weeds yet measured in those crops (Baysinger and Sims 1991; Harrison et al. 2001). Cotton growers in Tennessee often ask how many GR giant ragweed plants they can tolerate before they lose yield (Authors' personal experiences). Results from this research indicate that giant ragweed is one of the most competitive weeds to cotton in the United States. Growers need to control giant ragweed early in the growing season to maintain yield. Future studies should evaluate the interference potential of giant ragweed at various cotton growth stages and evaluate the effect of weed removal at different timings.

Acknowledgments

The authors would like to thank Patricia Brawley, Shawn Butler, Brian Kozlowski, Ernest Merriweather, Adam Rushing, and Matthew Wiggins for their assistance in establishment, maintenance, and harvest of these trials. This research was supported in part by Cotton Incorporated.

Literature Cited

Abul-Fatih, H. A. and F. A. Bazzaz. 1979a. The biology of *Ambrosia trifida* L. I. Influence of species removal on the organization of the plant community. New Phytol. 83:813–816.

Abul-Fatih, H. A. and F. A. Bazzaz. 1979b. The biology of *Ambrosia trifida* L. II. Germination, emergence, growth, and survival. New Phytol. 83:817–827.

Askew, S. D., W. A. Bailey, G. H. Scott, and J. W. Wilcut. 2002. Economic assessment of weed management for transgenic and nontransgenic cotton in tilled and nontilled systems. Weed Sci. 50:512–520.

Bassett, I. J. and C. W. Crompton. 1982. The biology of Canadian weeds. *Ambrosia trifida* L. Can. J. Plant Sci. 62:1003–1010.

Baylis, A. D. 2000. Why glyphosate is a global herbicide: strengths, weaknesses, and prospects. Pest Manag. Sci. 56:299–308.

Baysinger, J. A. and B. D. Sims. 1991. Giant ragweed (*Ambrosia trifida*) interference in soybeans (*Glycine max*). Weed Sci. 39:358–362.

Bazzaz, F. A. and R. W. Carlson. 1979. Photosynthetic contribution of flowers and seeds to reproductive effort of an annual colonizer. New Phytol. 82:223–232.

Bourland, F. M., N. R. Benson, E. D. Vories, N. P. Tugwell, and D. M. Danforth. 2001. Measuring maturity of cotton using nodes above white flower. J. Cotton Sci. 5:1–8.

Bryson, C. T. and M. S. DeFelice, eds. 2009. Giant ragweed. Page 53 *in* Weeds of the South. Athens, GA: University of Georgia Press.

Buchanan, G. A. and E. R. Burns. 1971. Weed competition in cotton. I. Sicklepod and tall morningglory. Weed Sci. 19:576–579.

Castner, E. P., D. S. Murray, N. M. Hackett, L. M. Verhalen, D. L. Weeks, and J. F. Stone. 1989. Interference of hogpotato (*Hoffmanseggia glauca*) with cotton (*Gossypium hirsutum*). Weed Sci. 37:688–694.

Cousens, R. 1985. A simple model relating yield loss to weed density. Ann. Appl. Biol. 107:239–252.

Duke, S. O. and S. B. Powles. 2009. Glyphosate-resistant crops and weeds: now and in the future. AgBioForum. 12:346–347.

Gianessi, L. P. 2005. Economic and herbicide use impacts of glyphosate-resistant crops. Pest Manag. Sci. 61:214–245.

Gibson, K. D., W. G. Johnson, and D. E. Hillger. 2005. Farmer perceptions of problematic corn and soybean weeds in Indiana. Weed Technol. 19:1065–1070.

Green, J. D., D. S. Murray, and L. M. Verhalen. 1987. Full-season interference of silverleaf nightshade (*Solanum elaeagnifolium*) with cotton (*Gossypium hirsutum*). Weed Sci. 35:813–818.

Hake, S. J., K. D. Hake, and T. A. Kerby. 1996. Preharvest/harvest decisions. Pages 73–81 *in* S. J. Hake, ed. Cotton Production Manual. Div. Agric. Natural Resources Publ. 3352. Oakland, CA: University of California, Oakland.

Harrison, S. K., E. E. Regnier, J. T. Schmoll, and J. E. Webb. 2001. Competition and fecundity of giant ragweed in corn. Weed Sci. 49:224–229.

Hartnett, D. C., B. B. Hartnett, and F. A. Bazzaz. 1987. Persistence of *Ambrosia trifida* populations in old fields and responses to successional changes. Amer. J. Bot. 74:1239–1248.

Heap, I. M. 2012. International Survey of Herbicide Resistant Weeds. www.weedscience.org. Accessed August 8, 2012.

Johnson, B., M. Loux, D. Nordby, C. Sprague, G. Nice, A. Westhoven, and J. Stachler. 2006. Biology and management of giant ragweed. Purdue Extension Publication GWC-12. www.extension.purdue.edu/extmedia/BP/GWC-12.pdf. Accessed August 8, 2012, 16 p.

Jurik, T. W. 1991. Population distributions of plant size and light environment of giant ragweed (*Ambrosia trifida* L.) at three densities. Oecologia 87: 539–550.

Klingaman, T. E. and L. R. Oliver. 1994. Palmer amaranth (*Amaranthus palmeri*) interference in soybean (*Glycine max*). Weed Sci. 42:523–527.

Loux, M. M. and M. A. Berry. 1991. Use of a grower survey for estimating weed problems. Weed Technol. 5:460–466.

Massinga, R. A., R. S. Currie, M. J. Horak, and J. Boyer, Jr. 2001. Interference of Palmer amaranth in corn. Weed Sci. 49:202–208.

Mercer, K. L., D. S. Murray, and L. M. Verhalen. 1987. Interference of unicorn-plant (*Proboscidea louisianica*) with cotton (*Gossypium hirsutum*). Weed Sci. 35:807–812.

Morgan, G. M., P. A. Baumann, and J. M. Chandler. 2001. Competitive impact of Palmer amaranth (*Amaranthus palmeri*) on cotton (*Gossypium hirsutum*) development and yield. Weed Technol. 15:408–412.

Norsworthy, J. K., P. Jha, L. E. Steckel, and R. C. Scott. 2010. Confirmation and control of glyphosate-resistant giant ragweed (*Ambrosia trifida*) in Tennessee. Weed Technol. 24:64–70.

Norsworthy, J. K., D. Riar, P. Jha, and R. C. Scott. 2011. Confirmation, control, and physiology of glyphosate-resistant giant ragweed in Arkansas. Weed Technol. 25:430–435.

Owen, M.D.K. and I. A. Zelaya. 2005. Herbicide-resistant crops and weed resistance to herbicides. Pest Manag. Sci. 61:301–311.

Rogers, J. B., D. S. Murray, L. M. Verhalen, and P. L. Claypool. 1996. Ivyleaf morningglory (*Ipomoea hederacea*) interference with cotton (*Gossypium hirsutum*). Weed Technol. 10:107–114.

Rowland, M. W., D. S. Murray, and L. M. Verhalen. 1999. Full season Palmer amaranth (*Amaranthus palmeri*) interference with cotton (*Gossypium hirsutum*). Weed Sci. 47:305–309.

Rushing, D. W., D. S. Murray, and L. M. Verhalen. 1985a. Weed interference with cotton (*Gossypium hirsutum*). I. Buffalobur (*Solanum rostratum*). Weed Sci. 33:810–814.

Rushing, D. W., D. S. Murray, and L. M. Verhalen. 1985b. Weed interference with cotton (*Gossypium hirsutum*). II. Tumble pigweed (*Amaranthus albus*). Weed Sci. 33:815–818.

Schutte, B. J., E. E. Regnier, and S. K. Harrison. 2008. The association between seed size and seed longevity among maternal families in *Ambrosia trifida* L. populations. Seed Sci. Res. 18:201–211.

Schutte, B. J., E. E. Regnier, and S. K. Harrison. 2012. Seed dormancy and adaptive seedling emergence timing in giant ragweed (*Ambrosia trifida*). Weed Sci. 60:19–26.

Snipes, C. E., R. A. Buchanan, J. E. Street, and J. A. McGuire. 1982. Competition of common cocklebur (*Xanthium pensylvanicum*) with cotton (*Gossypium hirsutum*). Weed Sci. 30:553–556.

SPSS. 2002. Sigma Plot 8.0 Programing Guide. Chicago, IL: SPSS. 320 p.

Steckel, L. E. 2007. Giant ragweed. University of Tennessee FACT sheet. W119. https://utextension.tennessee.edu/publications/Documents/W119.pdf. Accessed August 8, 2012.

Steckel, L. E. and C. O. Gwathmey. 2009. Glyphosate-resistant horseweed (*Conyza canadensis*) growth, seed production, and interference in cotton. Weed Sci. 57:346–350.

Stoller, E. W. and L. M. Wax. 1973. Periodicity of germination and emergence of some annual weeds. Weed Sci. 21:574–580.

Webster, T. M. 2005. Weed Survey–southern states: broadleaf crops. Proc. South Weed Sci. Soc. 58:291–304.

Webster, T. M., M. M. Loux, E. E. Regnier, and S. K. Harrison. 1994. Giant ragweed (*Ambrosia trifida*) canopy architecture and interference studies in soybean (*Glycine max*). Weed Technol. 8:559–564.

Received October 25, 2012, and approved May 8, 2013.